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A MODERN MILITARY GRID SYSTEM

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A MODERN MILITARY GRID SYSTEM

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In more recent years, it has become almost axiomatic that for military purposes some system of plane rectangular coordinates, as opposed to geodetic coordinates of latitude and longitude, is essential to the efficient and rapid utilization of fire control data under battle conditions. Speed and simplicity in the determination of accurate direction and distance between points and a quick means for clearly defining the location of a point for reference purposes are paramount considerations in the adoption of a suitable military projection and grid. The comparatively cumbersome calculations required for direction and distance from geodetic coordinates have forced the military authorities of practically all nations to adopt the simpler system of plane rectangular coordinates.

As far back as 1917, when the United States became involved in the First World War, the need was recognized for a plane rectangular system mainly for the use of the Artillery. At that time, the U. S. Coast and Geodetic Survey, with the aid of enlisted personnel from the Army, computed the Polyconic grid tables for the five-minute intersections of latitude and longitude on the Clarke 1866 Spheroid. This was the official military grid of the Army throughout both world wars and until 1947 when it was abandoned in favor of the new military grid and reference system known as the Universal Transverse Mercator.

Conformality in a projection is the property otherwise called "orthomorphic" which comes from the Greek word meaning "same shape." Thus, in a conformal projection, an area on the map retains the same shape as on the ground and the angles are correct, over reasonably limited areas, and the scale is equal in all directions from a point. In a non-conformal or non-orthomorphic projection, such as the Polyconic, none of the above three characteristics is present with the result that a distortion occurs in all northerly-southerly directions of a nature which is intolerable, particularly to the Artillery. Prior to the adoption by the Army of the Universal Transverse Mercator System in 1947, the United States was the only major country in the world which used a non-conformal projection for military purposes.

A map projection is indicated by a mathematical representation of the latitude and longitude lines of a geometric figure of the spheroidal earth on to a plane surface; a grid is a regular system of parallel lines, equally spaced and at right angles to each other, superimposed on the projection. The true Mercator projection in almost universal use by navigators projects the features of the earth on to a cylinder tangent at the equator. The Transverse Mercator is difficult to picture but is perhaps best described as the projection of a limited portion of the earth's

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surface on to a cylinder at right angles to the true Mercator, or tangent to a meridian. The cylinder is then rolled out on to a plane and the grid superimposed on the projection as indicated above.

The Transverse Mercator is not new as such; it was invented by Gauss early in the Nineteenth Century and is still referred to by perfectionists as the Gauss Projection. The Transverse Mercator Projection in six-degree bands was proposed by the International Union of Geodesy and Geophysics in 1936 and was recommended to the Army in 1941 by the U. S. Coast and Geodetic Survey to replace the Polyconic. The Germans and the Russians, at least, had used the Transverse Mercator for many years as their military projection and grid.

In 1944, the Chief of the Geodetic Branch in the Office of the Chief of Engineers, U. S. Army, called an initial consultation of interested geodesists to consider the desirability of a new grid system. At that meeting, it was decided to recommend the adoption of the Transverse Mercator projection and grid for official use by the Army to replace the nonconformal Polyconic. Included in the recommendation from this meeting were several special provisions to be incorporated in the system, among which were a scale reduction of one part in 2500 on the central meridian, an extent of coverage from 80° South Latitude to 80° North Latitude, the use of the metric to replace the English system used in the Polyconic, and a one-degree overlap at all zone junctions. Subsequently, the one-degree overlap was modified to provide for a uniform 50 miles throughout, and a stereographic system was recommended for the polar caps.

Owing to the contemplated use of the new projection and grid systems by the Army in its world-wide mapping program and to the new features incorporated therein, as well as to their possible adoption by other nations, it was thought appropriate to designate them as the Universal Transverse Mercator and the Universal Polar Stereographic, respectively. The Army Map Service later devised the reference systems for point designation which are corollaries to and based directly upon these two systems. These reference systems are unique in their provision that no two points in the world can have the same designation.

The basic consideration of a projection and grid system satisfactory for military purposes, for reasons cited above, is that it must be conformal in order that true shapes are preserved over reasonably large areas. Other desirable features are:

a) That the grid system shall have a minimum number of zones or junctions for the desired minimum accuracy without the necessity for the application of scale corrections.

b) That one transformation table shall suffice for the conversion of coordinates between adjacent zones for any one spheroid.

c) That one table only shall be required for a spheroid, throughout the entire system, for the computation from geographic to grid coordinates and one table for the inverse computation.

d) That the east-west span of the grid zone shall be limited to the extent that the divergence of grid north from the meridian will not be troublesome, perhaps not more than four or five sexagesimal degrees at the most.

e) That the grid shall adapt itself readily to a unique map reference system for point designation.

In weighing the qualifications of the various conformal systems and considering that the projection and grid must be world wide in application while retaining the desired features, the choice, except for the Polar areas, quickly narrowed down to two, viz., the Lambert conic-conformal and the transverse Mercator. The Lambert satisfied conformality but could not be made to comply with the items (b), (c), and (e) of the requirements. Compliance with item (d) would cause it to fail in item (a). However, the transverse Mercator was conformal and could be modified to satisfy all five of the specified items. For the polar caps, where the transverse Mercator is not practicable due to the high convergence of the meridians, there seemed to be but the one choice, that of the stereographic. Here item (d) had to be foregone and the relation to true north dispensed with except for general index purposes.

It was only after a most exhaustive analysis by the Army Map Service, by the ground forces and other units of the Army, of the entire question of a most suitable projection and grid, taking into account all factors involved, that the United States Army, in 1947, adopted the Universal Transverse Mercator and the Universal Polar Stereographic projection, grid, and reference systems as official to replace the Polyconic as rapidly as practicable to do so. Later, in 1949, the Joint Chiefs of Staff directed that these systems be used by land, sea, and air forces in all combined military operations. (See Figs. 1, 2, and 3.)

Immediately following the adoption of the new system by the Army in 1947, the Army Map Service proceeded to implement the directive as rapidly as its facilities would permit. At the same time, through correspondence and at various international conferences, it successfully presented the logic of this standardized system to many other friendly countries. In this endeavor, it was greatly assisted by the fact that the International Union of Geodesy and Geophysics, with a present membership of some 42 nations, had expressed the "wish that the attention of all countries, who have charge of preparing maps for the different parts of Africa, be directed to the existing interest in the adoption of projection systems for the whole continent referred to one general system." This reference to Africa was further extended to all continents and countries by a resolution of the Union at its Brussels meeting in 1951. The Commonwealth Survey Officers' Conference in London, also in 1951, reinforced the Union action by a resolution recommending the Universal Transverse Mercator System for the countries of Africa. At the Ciudad Trujillo session of the Commission on Cartography of the Pan American Institute of Geography and History last October, that assembly recommended favorable consideration of the System to all countries of the Antilles, Central and South America.

The Army Map Service is the United States depository for the geodetic data of the world and has the responsibility for processing it to usable form for the operational use of our three military services, the Army, the Navy, and the Air Force. It has in its files the coordinates of approximately three million horizontal control stations of various countries of the world. The computation of this mass of data to the new military grid is far advanced. It is only feasible through the use of the most modern mass computing facilities, including the recently designed electronic digital equipment now on hand at the Army Map Service. The

processing of geodetic data of the world to usable form for military purposes consists not only in procurement, analysis, translation, and computations, but in the preparation and publishing of numerous trig lists giving all necessary descriptive information on the control stations, including their Universal Transverse Mercator grid coordinate positions and their elevations. Four thousand of these trig lists, containing an average of 200 points each, have been published and the work is continuing on a priority basis.

In order to make most effective use of the standardized Universal Transverse Mercator projection and grid, it is highly desirable that the triangulation control of whole continents be reduced to a single geodetic datum involving one figure of the earth, all based on a common least squares adjustment. Examples of this are the first-order triangulation networks of North America and the recently completed adjustment of the first-order triangulation of Europe and Northwest Africa. Continental adjustments of the major triangulation of Africa and that of South America are currently proposed at the Army Map Service following the completion next year of the existing gap in the arc of the 30th Meridian in Africa and the extensive operations of the Inter-American Geodetic Survey in South America. Eventually, through the inter-continental ties now possible by modern methods utilizing solar eclipses and star occultations, geodesists envision a single geodetic datum for the entire globe. The determination of a new figure of the earth is now underway at the Army Map Service. It will make use of the extensive long arcs of triangulation, astronomic stations, and gravity observations, throughout both hemispheres, which were not available when the Hayford International Ellipsoid was computed some fifty years ago. A world geodetic datum calls for the use of this greatly increased information in order to arrive at improved values for the parameters of the figure which best fits the geoid as a whole or, at least, a verification of the present International Ellipsoid.

Implementation of the new Universal Transverse Mercator Grid and Reference System has involved and continues to require not only the reduction of masses of geodetic data to usable form and the preparation of trig lists but also the conversion to the new grid of many thousands of military topographic maps of various scales throughout the world. This conversion of existing map coverage to the new grid has been simultaneous in nearly all areas with the reduction of the numerous geodetic datums to different and fewer datums, often including a change in the previous ellipsoid. Therefore, in addition to the transformation of coordinates of geodetic control stations and their least square adjustments to the new datums, it has been necessary to compute and tabulate UTM sheet corner values for the thousands of map sheets mentioned above. Electronic computing equipment has been used and is the answer to this problem also.

Fortunately, in changing the grid and even the geodetic datum on a map, it is not necessary to redraft the contours and other features as might be supposed at first. A far more economical plan was adopted at the Army Map Service whereby the original native sheet lines of the map were retained unaltered. It was necessary only to prepare a new grid plate using the machine computed and tabulated sheet corner data.

With the substitution of the new UTM grid plate, every feature on the map is automatically transferred to the new datum and grid. Where the sheet lines were originally on even minutes of latitude and longitude, this process results in slightly odd values at the corners. This is not objectionable, however, since the latitude and longitude lines on the military map serve only as an index whereas the plane UTM coordinates are used exclusively for military purposes.

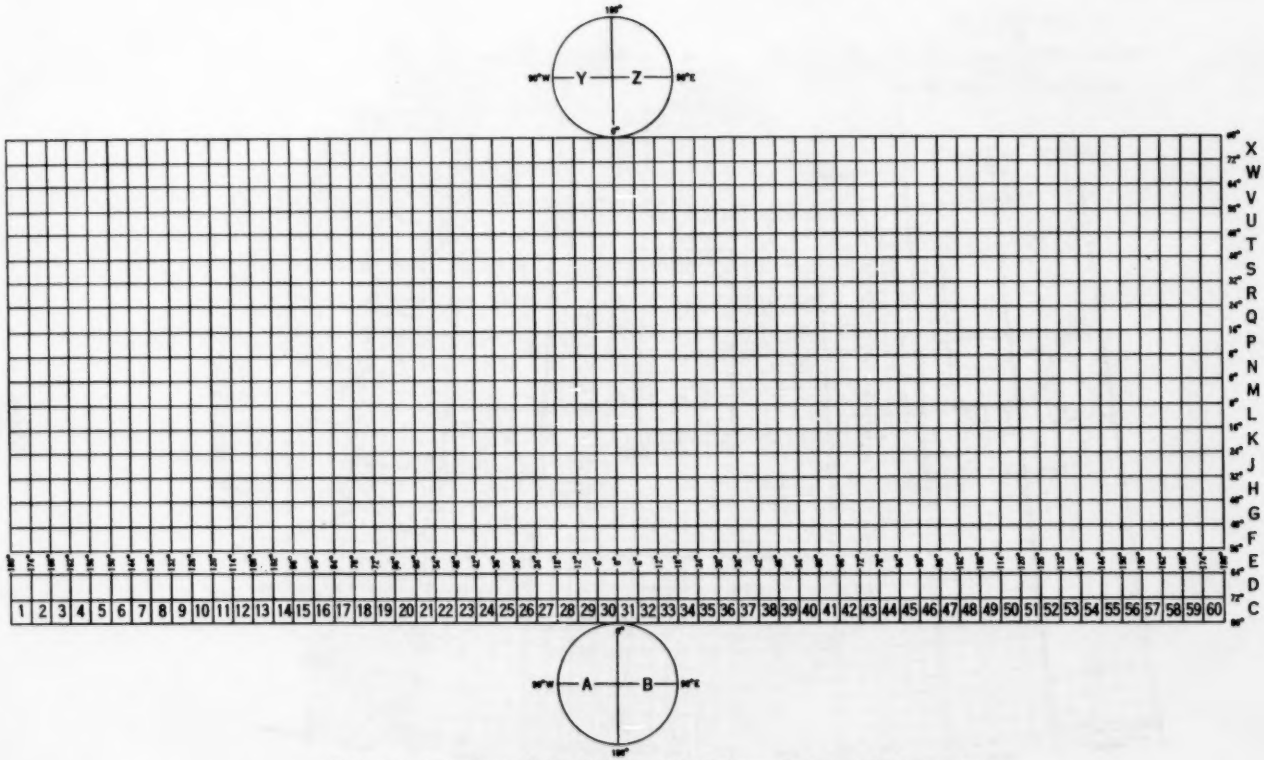
Over the past 36 months, the UTM grid conversion program has been vigorously carried on by the Army Map Service in cooperation and in collaboration with other interested countries. Much remains to be done. The changeover from the old grid to the UTM takes place on certain dates agreed upon internationally and by large area blocks, usually covering several countries at a time. This conversion date is predicated on the completion of map conversion of all scales, the publication of trig lists, the substitution of UTM map stocks, and the accomplished distribution of these items to the appropriate military units. On the designated conversion date, all previous maps and grids in the area automatically become obsolete.

An undue number of grid junctions is a well recognized liability in an area of military operations. These junctions are especially difficult for the artillery when the method of transformation between adjacent zones is not uniform. I should like to point out one important area in which the UTM grid has contributed much to the reduction of troublesome grid junctions. In Europe, west of a meridian through Moscow, the previous grid system consisted of twenty different zones with a total of forty junctions on nearly all of which a different type of transformation was involved in passing from one zone to the adjacent zone; with the substitution of the standard UTM in this area, the zones are reduced from twenty to eight and the number of junctions from forty to seven with identical transformation formulas at all seven junctions. In addition, the twenty zones required a separate computation table for nearly every zone whereas only one table is needed for any number of UTM zones on the same spheroid.

The Universal Transverse Mercator and the Universal Polar Stereographic systems were carefully designed to meet requirements of a suitable grid system for the world-wide military mapping program of the Army Map Service and for general military operations of the United States Army. It was never intended, and the Army Map Service has not so recommended, that they should replace the cadastral grids of any nation. We retain our own State Plane Coordinate Systems in the United States for cadastral purposes. It is a distinct advantage in cadastral as well as military surveys to avoid the necessity for the application of scale corrections to the measured lengths on the ground. Most cadastral grids, since they involve smaller areas, employ narrower zones, with more junctions, thus retaining a maximum scale correction of about one part in 10,000. A military grid system with world-wide coverage, on the other hand, demands the minimum number of different zones and junctions which will yield the required accuracy without scale corrections. The UTM fully satisfies military requirements in this respect as its accuracy without scale corrections is one part in 2500, or better, in all areas of latitude higher than 45^{o}, while in lower latitudes it slowly

drops until it reaches one part in 1000 at the equator, but then only at the extreme edges of the zones in this region of lesser military importance. It must be emphasized, however, that when the simple scale corrections are applied to ground measurements, the UTM is fully as good as the original ground survey permits, even to the standard of first-order accuracy. For this reason, certain countries, preferring to employ but one grid for all purposes, have adopted the UTM for cadastral as well as military use. Since both cadastral grids and the UTM are conformal, it is a simple matter, at the Army Map Service, to receive the data in a cadastral system and transform them to the UTM through the use of modern computing equipment. The accuracy and feasibility of the Universal Polar Stereographic grid system in the land areas are comparable to the UTM.

The extension of the UTM to combined operations of the three military services, its acceptance by the North Atlantic Treaty Organization and by various other countries as their official military grid system, the recommendation for its wide adoption for topographic mapping by such international organizations as the International Union of Geodesy and Geophysics, and the Pan American Institute of Geography and History, as well as by the British Commonwealth Survey Officers' Conference, and, particularly, its acclaimed use during the past three years in the military operations of Korea, all attest the soundness in the design and the adaptability of the new system. There is ample evidence that these modern grid systems, the Universal Transverse Mercator and the Universal Polar Stereographic, represent a distinct and important advance in military engineering in keeping with the wide technical progress of our age.



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Grid zone designations of the Military Grid Reference System. The designations identify the polar areas and 6°E.—W. by 8°N.—S. divisions of the globe between 80°N. and 80°S.

Fig. 1

PLATE II-16

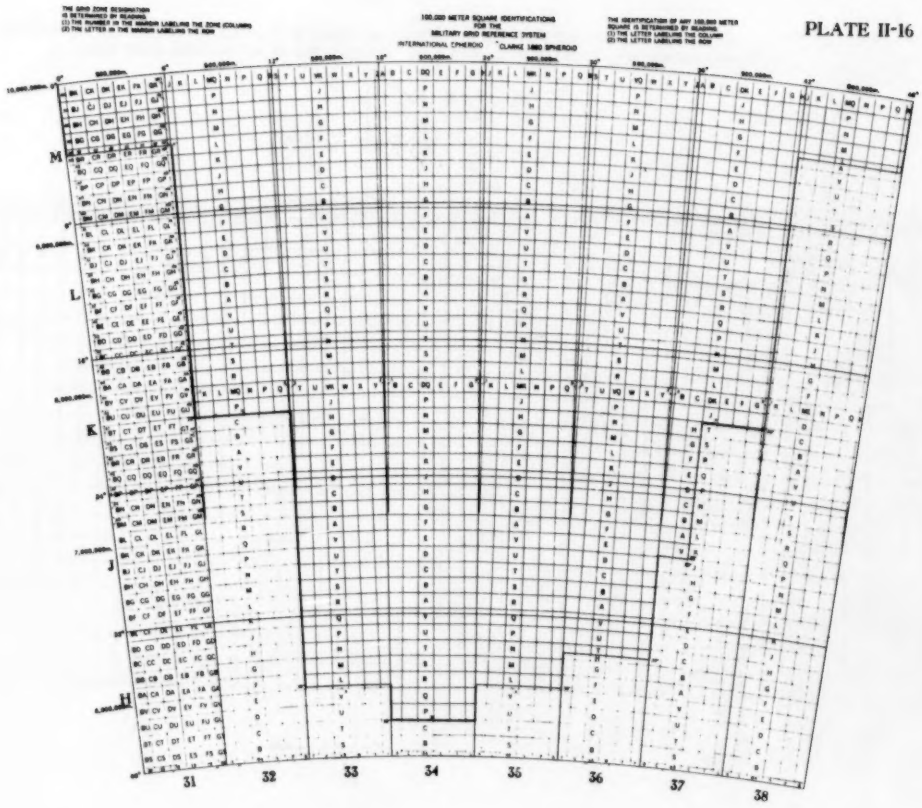
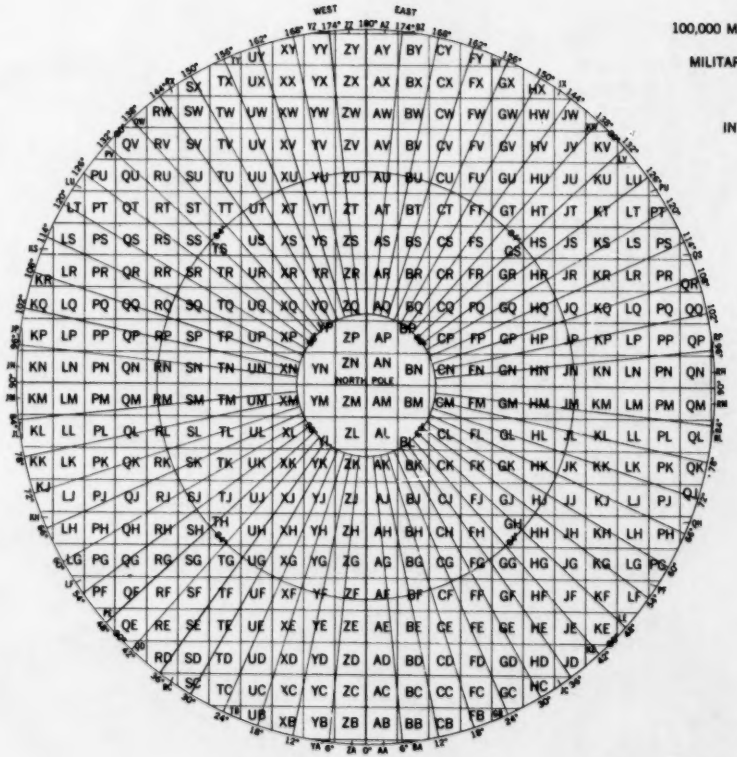


Fig. 2

PLATE II-1

100,000 METER SQUARE IDENTIFICATIONS
FOR THE
MILITARY GRID REFERENCE SYSTEM

INTERNATIONAL SPHEROID



GRID ZONE DESIGNATIONS

Fig. 3

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